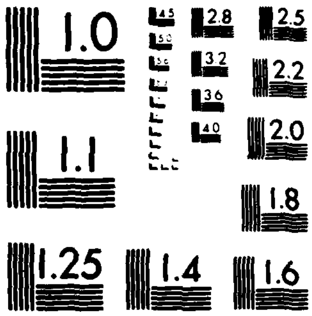
AD-A146 396 DEFORMATION FRACTURE AND EXPLOSIVE PROPERTIES OF REACTIVE MATERIALS(U) CAMBRIDGE UNIV (ENGLAND) CAVENDISH LAB J E FIELD ET AL. JUN 84 R/D-4380-R-AN 1/1

UNCLASSIFIED DAJA45-84-C-0018 F/G 19/1 NL

END
DATE FILMED
11-84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A146 396

DEFORMATION, FRACTURE AND EXPLOSIVE

PROPERTIES OF REACTIVE MATERIALS

1. SUMMARY OF RESEARCH

In this interim report we summarise progress in five areas of research. A detailed account will be given in the final report.

(a) Drop-weight impact studies

These have been made using the facilities developed in early work, and described by Heavens and Field [1]. Figure 1 illustrates our transparent anvil drop-weight apparatus which allows us to photograph events at microsecond framing rates. Figure 2 is an instrumented drop-weight machine which allows us to record pressure-time curves. Earlier results for a wide range of explosives are desctibed in references [1-3].

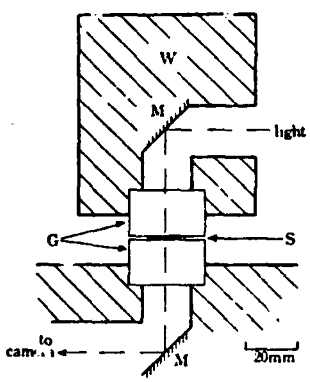


Fig. 1. Experimental arrangement at instant of impact: W, drop weight; G, glass blocks; M, mirror; S, sample. The upper glass block G is attached to the drop weight.

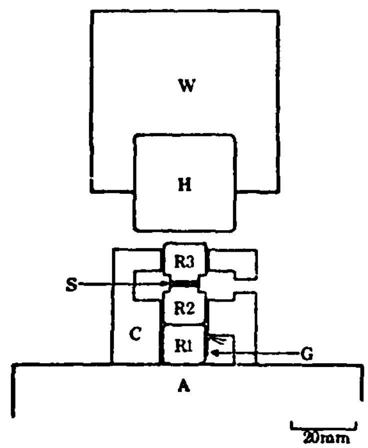


Fig. 2. Experimental arrangement for obtaining pressure-time curves: W, drop-weight; H, R1, R2, and R3, hard steel rollers; C, cylindrical guiding sleeve; S, sample; G, strain gauge; A, cast steel anvil.

In the grant period, we have made a detailed study of hexanitrostilbene (HNS) and have compared its behaviour with a range of other explosives. The photographic sequences show that upon impact the layer of explosive undergoes bulk plastic flow at speeds of over 250 m s^{-1}. Initiation occurs after this catastrophic failure. From a comparison of melting points, uniaxial yield stress values, flow properties and the ignition characteristics of several organic secondary explosives, it appears that explosives with high strength values are more likely to exhibit both a rapid mechanical failure and resultant ignition during impact. Table 1 summarizes the results, which emphasize the important relation between mechanical properties and ignition characteristics.

TABLE

Strength Properties and Impact Behavior of Various Materials

Compound	Melting point (K)	Yield stress (MPa)	H_{50} (m)	Observations in Impact Apparatus: Rapid Flow	Ignition
TNT	354[a]	34[b]	1.48[c]	No[d]	No
Picric acid	395	52	0.73	No	No
Tetryl	404	53	0.37	No	Yes[e]
PETN	414	60	0.13	Yes	Yes
RDX	474	82	0.28	Yes	Yes[f]
Ammonium perchlorate	>493	–	–	Yes	Yes
HMX	553	128	0.32	Yes	Yes
HNS	588	~140	0.54	Yes	Yes
Potassium nitrite	>660	–	–	Yes	–

[a] Values taken from Lawrence Livermore National Laboratory Explosives Handbook, UCRL-52997 (1981).
[b] All the yield stress values from Ref. [10] except for HNS, which has been estimated using Eq. (3).
[c] Drop-weight, 2.5 kg; sand paper surface. Data from reference given above in table footnote a.
[d] The experimental observation. for all compounts excluding tetryl and HNS are from Ref. [1].
[e] Reaction fails to propagate.
[f] Ignition with large masses (100 mg) only.

(b) Deformation stress of explosive crystals from contact area measurements

Relatively little is known about the yield stresses of single crystals of explosives. One of us (M.M. Chaudhri) has been using a novel technique to measure the deformation stresses of millimetre-sized single crystals of explosives. The technique involves loading the test crystal against a transparent glass plate with "in situ" measurements made of the real area of contact under load using an optical microscope. For all the crystals studied, the deformation stress was found to increase with load reaching a plateau at higher loads. The maximum deformation stress of a crystal was found to be considerably lower than its Vickers diamond hardness value. Results are summarized in Table 2. A full account is being prepared for publication.

TABLE 2

Comparison of maximum deformation stress
of a particle and its Vickers diamond hardness

Material	Vickers diamond hardness H_v/kg mm^{-2}	Maximum deformation Pressure of particle Pm/kg mm^{-2}	P_m/H_v
α - lead azide (PbN_6)	119.74 ± 8.1	27.5*	0.23
RDX	24.1 ± 0.8	15*	0.62
β-HMX	41.3 ± 1.0	26*	0.63
LAT (type C)	109.4 ± 3.1	29*	0.27
LAT (type A)	34.5 ± 0.9	12*	0.35
KCl	16 ± 1	2.8*	0.18

*error ≲ 5%

(c) Recording of "hot-spots"

An interesting method for recording "hot-spots" during impact deformation is to use heat sensitive film. This was first suggested by Coffey and Jacobs [4]. We have considerably extended this technique. The film has now been calibrated over a wider range of temperatures and times (the colouration is a function of both temperature and time). Further, by using our transparent anvil drop-weight apparatus we have been able to record the time-scale of events and hence obtain "hot-spot" temperatures as well as locations.

(d) Studies on PBX explosives

We are interested in the relation between the mechanical and thermal properties of PBX explosives, their sensitiveness (response to a prescribed stimulus) and their explosiveness (explosive response). Recently we have investigated a range of PBX explosives based on H.M.X.

The variables have been (i) the particle size of the H.M.X. (ii) the type of polymeric binder (polyethylene, polyurethane, viton) and the % of binder. We have observed their behaviour in the drop-weight tests (see Figs. 1 and 2), have measured their tensile strengths and rupture strains at strain rates of ca. 10^{-4} s^{-1}, using the Brazilian test geometry and laser speckle photography and their high strain rate properties at strain rates of 2.5×10^{4} s^{-1} using special techniques developed in this laboratory. Full details of the techniques and results will be given in the final report.

(e) <u>Thermal, fracture and laser-induced decomposition of PETN</u>

This project was started on an earlier contract. It has recently been completed and prepared for publication [5]. The Abstract of the paper is given below, the full text will appear in the final report.

This paper describes a study of the decomposition of pentaerythritol tetranitrate (PETN) using a high-resolution time-of-flight mass spectrometer. The decomposition was induced by fracturing single crystals and by laser irradiation. In the fracture experiments, the energy input was varied from the lowest level necessary to produce smooth cleavage surfaces to high energy loading which produced rough conchoidal fracture surfaces. In the laser experiments, a ruby laser was used in both normal and Q-switched modes, and again the energy input was varied. For all the various experiments, the reaction products were analysed and reaction schemes are proposed. It is shown that low energy fracture causes decomposition which follows the same reaction pathway as that induced thermally, with initial failure at the $RO\text{-}NO_2$ bond. However, high energy fracture results in the breaking of the C-C bonds. Two reaction pathways were observed with the laser irradiation. The first is the normal thermal process, but evidence was also found for failure at the $R\text{-}ONO_2$ bond. The reaction continued for several milliseconds after the end of the laser pulse suggesting a 'partial' ignition of the explosive. In other experiments, the conditions for laser initiation of PETN in vacuum were investigated. Explosion occurred when Q-switched pulses of 1 J energy were applied to a molten layer of PETN.

References

1 Heavens S.N. and Field J.E.

1974 Proc. Roy. Soc. Lond A338. 77

2 Swallowe G.M. and Field J.E.

1981 Proc. Roy. Soc. Lond A379. 389

3 Field J.E., Swallowe G.M. and Heavens S.N.

1983 Proc. Roy. Soc. Lond A382. 231

4 Coffey C.S. and Jacobs S.J.

1981 J. Appl. Phys. 52. 6991

5 Ng W.L., Field J.E. and Hauser H.M.

1984 Proc. Roy. Soc. Lond (Submitted)

2. FUTURE RESEARCH

(a) Further work on mechanisms of "hot-spot" production during impact and shock, including photography of impact on single crystals of HMX of different sieved sizes.

(b) Further experiments with heat sensitive film to measure temperatures at "hot-spots" in deforming layers of (i) pure explosives (ii) PBX's and (iii) explosives + additives.

(c) Further work on PBX's including drop-weight impact, strength and rupture properties and mechanical properties at high rates of strain.

3. CONFERENCES, etc.

Drs. Field and Swallowe attended the 3rd Int. Conf. on High Rates of Strain, Oxford, U.K. April 1984.

Dr Field gave an invited review "Impact Erosion Properties" and a paper on "High Strain Rate Properties of Explosives". The group also made two Poster Presentations ("Heat generated during impact on polymers" and "Progress in metal testing with 3mm pressure bar").

Drs. Field and Chaudhri attended a Conference sponsored by the U.S. Army ERO on "Fast Reactions in Energetic Materials" held at the

Royal Institution, London, May 1984. Dr Field gave a review paper on "The Application of High Speed Photography for Studies of Explosive Events".

ND

ATE

LMED

84

TIC